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The RSS/NASA SMAP Salinity Version 3 Release

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Remote Sensing Systems

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Outline

- Overview of RSS SMAP V3 Release
  - Improvements over V2
  - Performance
  - Data Distribution
- Spatial Sampling and Noise Figures
- V3 Retrieval Algorithm
  - Geophysical Model
  - Ancillary Wind Speed
  - Emissive SMAP Reflector
  - Land Correction
- Aquarius – SMAP Continuity (NASA SCPS)

SMAP – ARGO (Scripps)
rain filtered, open ocean

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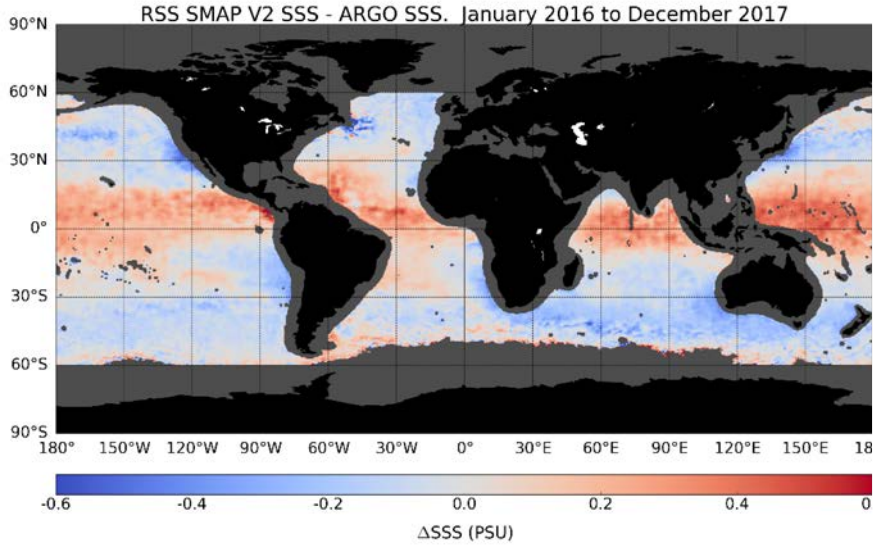
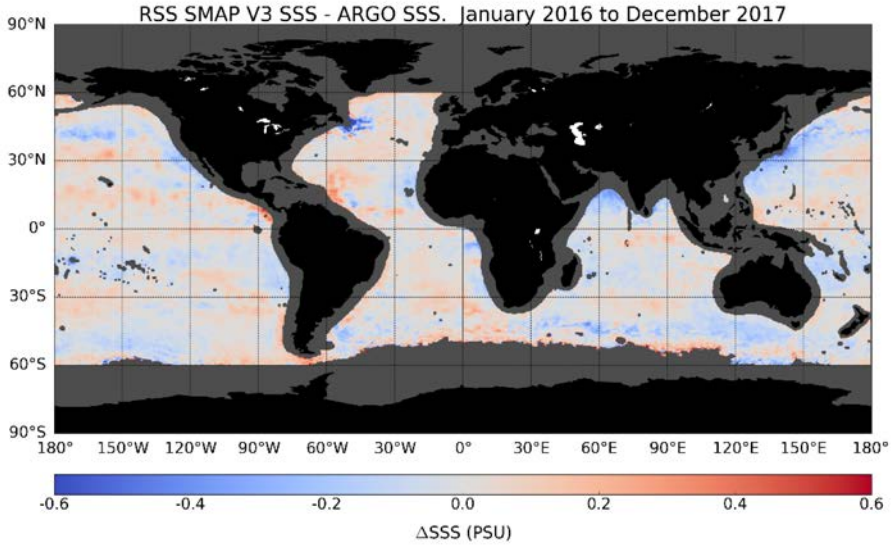
V2.0

V3.0

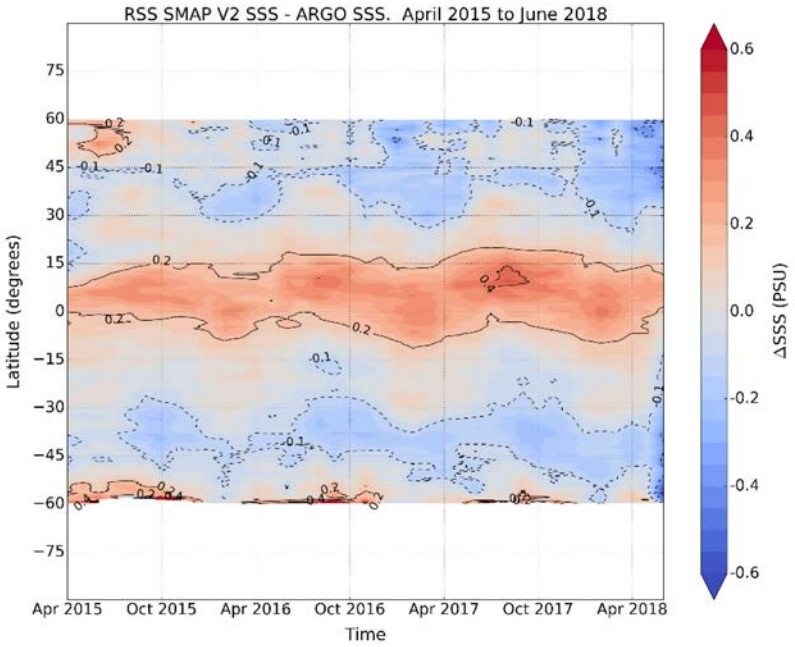




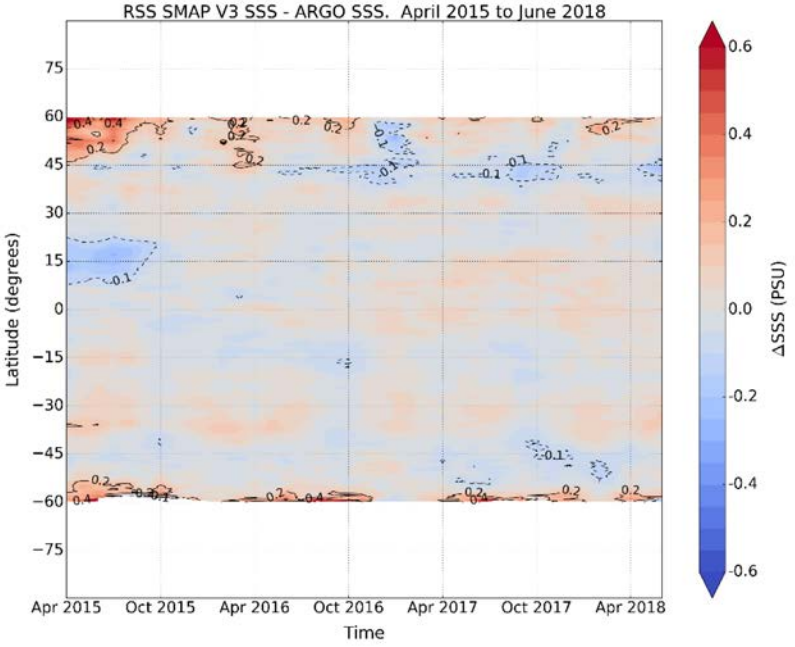
V3 removes spurious salty biases in the tropics that were prevalent in V2.

SMAP – ARGO (Scripps)
rain filtered, open ocean

V2.0



V3.0

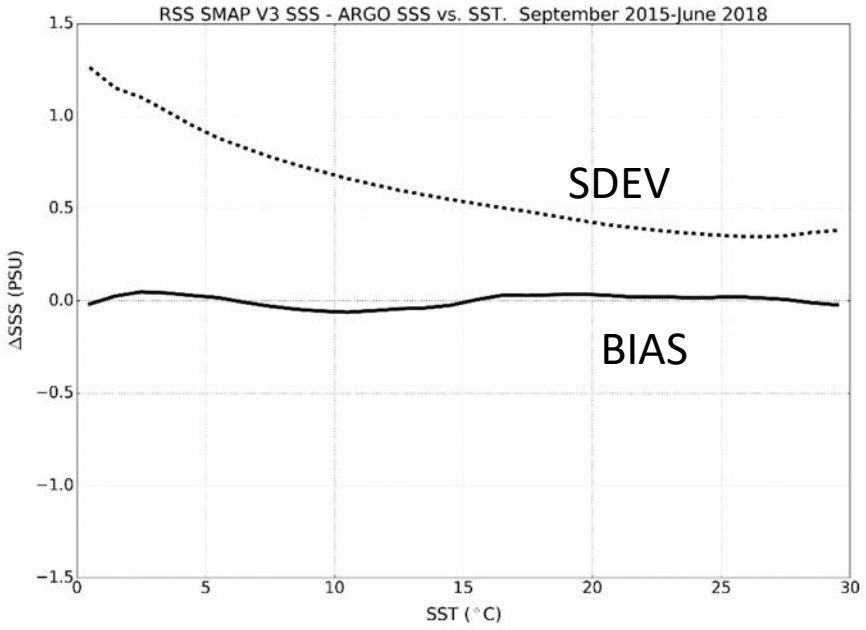


V3 removes spurious salty biases in the tropics that were prevalent in V2.

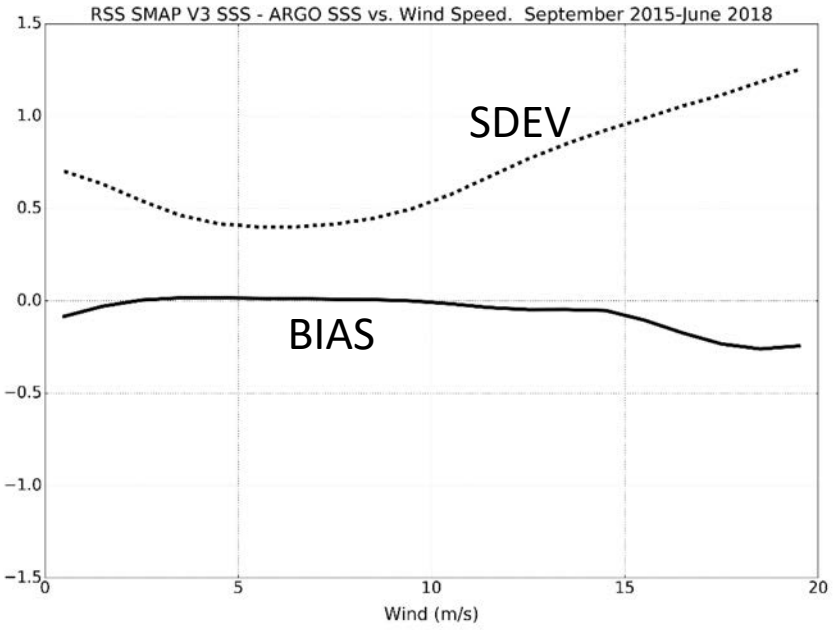
RSS SMAP V3.0 Level 2 – ARGO

Open Ocean. Binned v SST and Wind Speed

VS. SST



VS. WIND SPEED



No biases over whole SST range and wind speed range (< 15 m/s).
Even in cold water.
Consistency of GMF (dielectric model, wind emissivity model).

SMAP (V3) – ARGO – HYCOM

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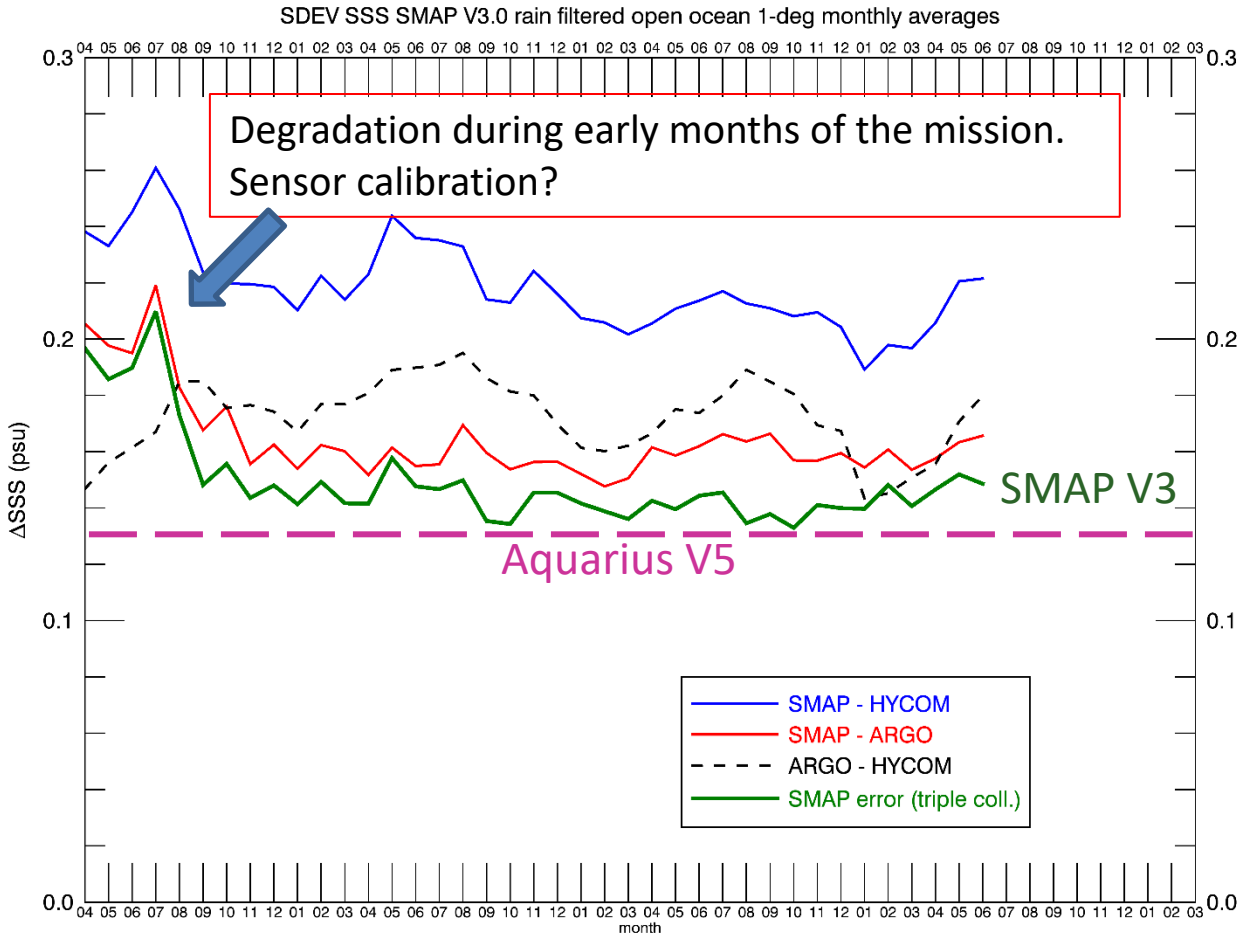
Triple Collocation. 1-deg Monthly Averages.

SMAP V3 reaches quality of Aquarius V5



NASA/RSS SMAP V3 SSS

Data Products

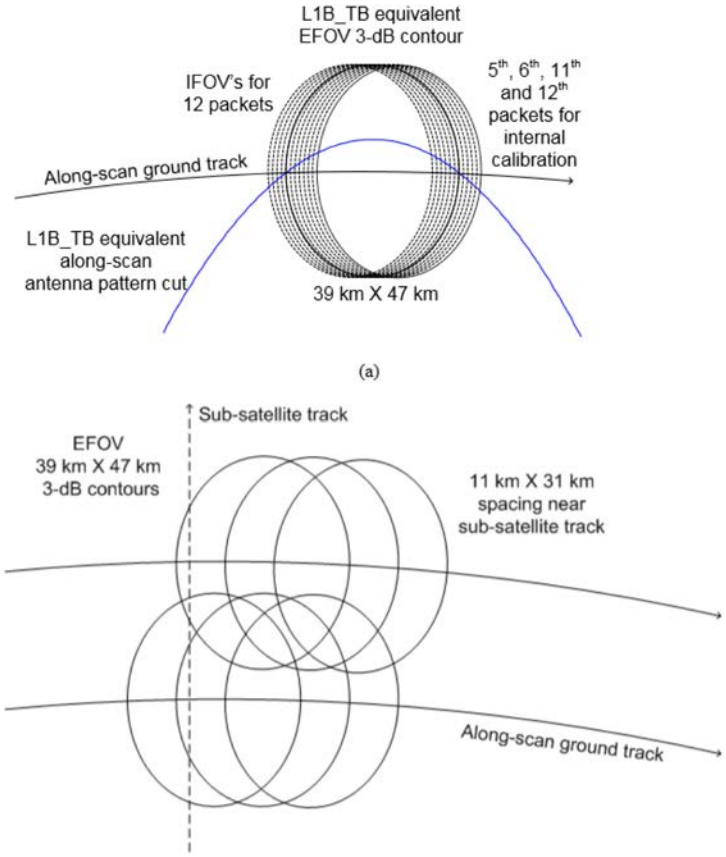
40 km	70 km standard product	content	latency
L2C	L2C	¼ deg swath grid SSS + all essential orbital and pointing parameters, all TA, TB, ancillary fields, all corrections, forward model (TA expected)	~ 1 day
L3 8-day running	L3 8-day running	¼ deg map SSS + land fraction, sea-ice fraction, SST	~ 1 week after center day
L3 monthly	L3 monthly	¼ deg map SSS + land fraction, sea-ice fraction, SST	~ 1 week after end of the month
	L3 monthly rain filtered (RF) @ RSS only	¼ deg map SSS + land fraction, sea-ice fraction, SST	

RSS www.remss.com/missions/smap/salinity

NASA PO.DAAC ftp://podaac-ftp.jpl.nasa.gov/allData/smap/

SMAP

Footprint – Sampling – Noise



from SMAP L1B ATBD (J. Piepmeier et al.)

L1B sampling time:

- Aquarius: 1.44 sec (pre-averaged)
- SMAP: ~ 14 msec (EFOV)

results in 10 times larger noise in SMAP L1B
strongly oversampled (overlap between EFOV)

Noise figure for SMAP L1B EFOV is ~ 2 psu.

- All random noise.
- **Useless** for most oceanic applications.

RSS/NASA SMAP L2 processing resamples SMAP L1B using Backus-Gilbert type Optimum Interpolation (OI) onto fixed ¼ deg Earth grid.

- Utilize over-sampling in along-scan direction.
- 40 km elliptical (keep original resolution)
- **70 km circular**

SMAP

Approximate Noise Figures + Spatial Resolution for Salinity Product

Product	Spatial Resolution	Noise	Noise Type
SMAP L1B	40 km	~ 2 psu	random (NEDT)
RSS SMAP L2	40 km OI	~ 0.9 psu	random (NEDT)
RSS SMAP L2	**70 km OI**	**0.5 psu**	**random (NEDT) + systematic (GMF)**
RSS SMAP L3 monthly	**70 km**	**0.15 psu**	**systematic (GMF)**

The OI results in a significant noise reduction of an otherwise extremely noisy product.

For most open ocean applications, the 70-km products are the best to use as they have significantly lower noise.

Salinity Retrieval

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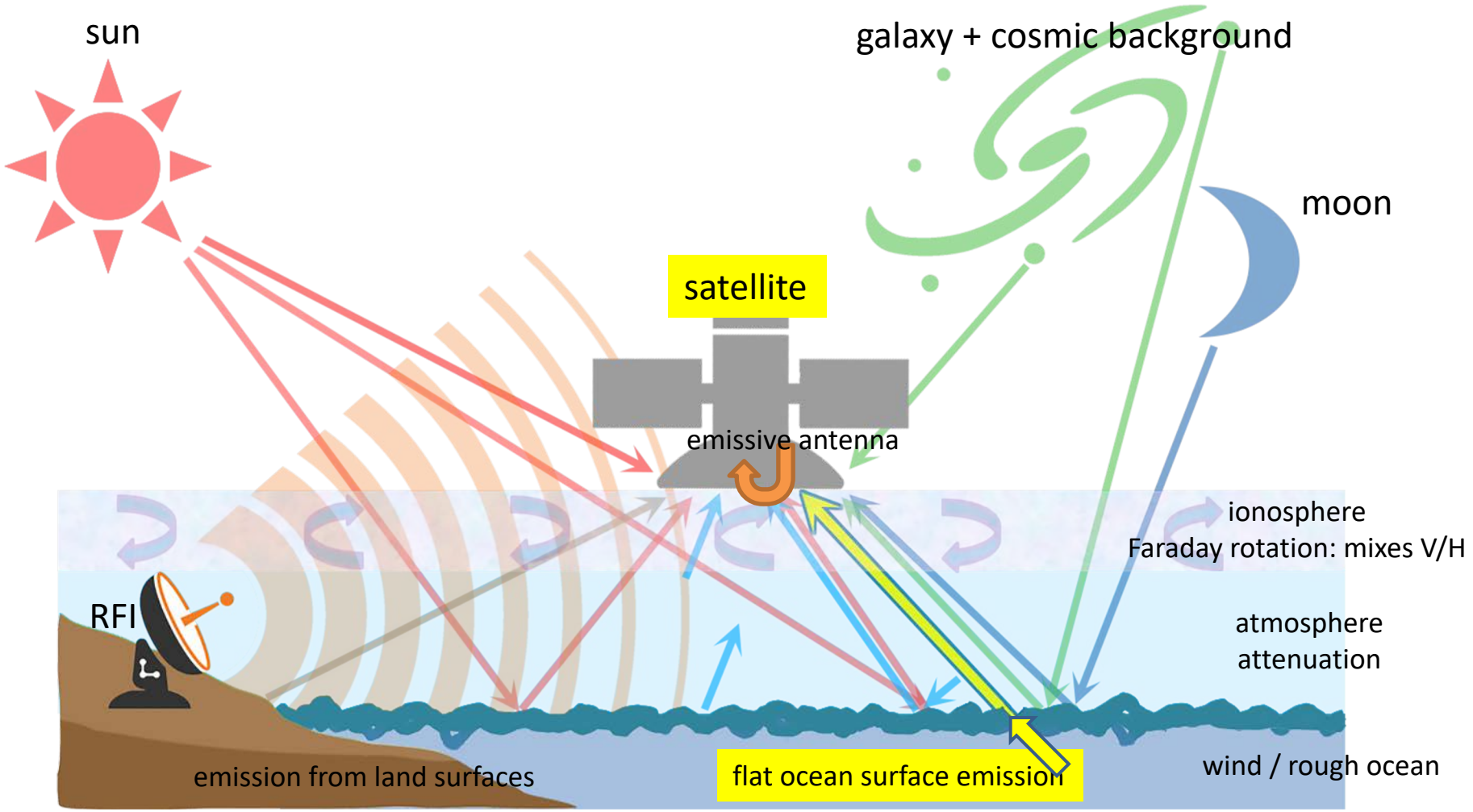
Large spurious signals
Only about 10% of the received signal comes from SSS



Credit: A. de Charon, U of Maine

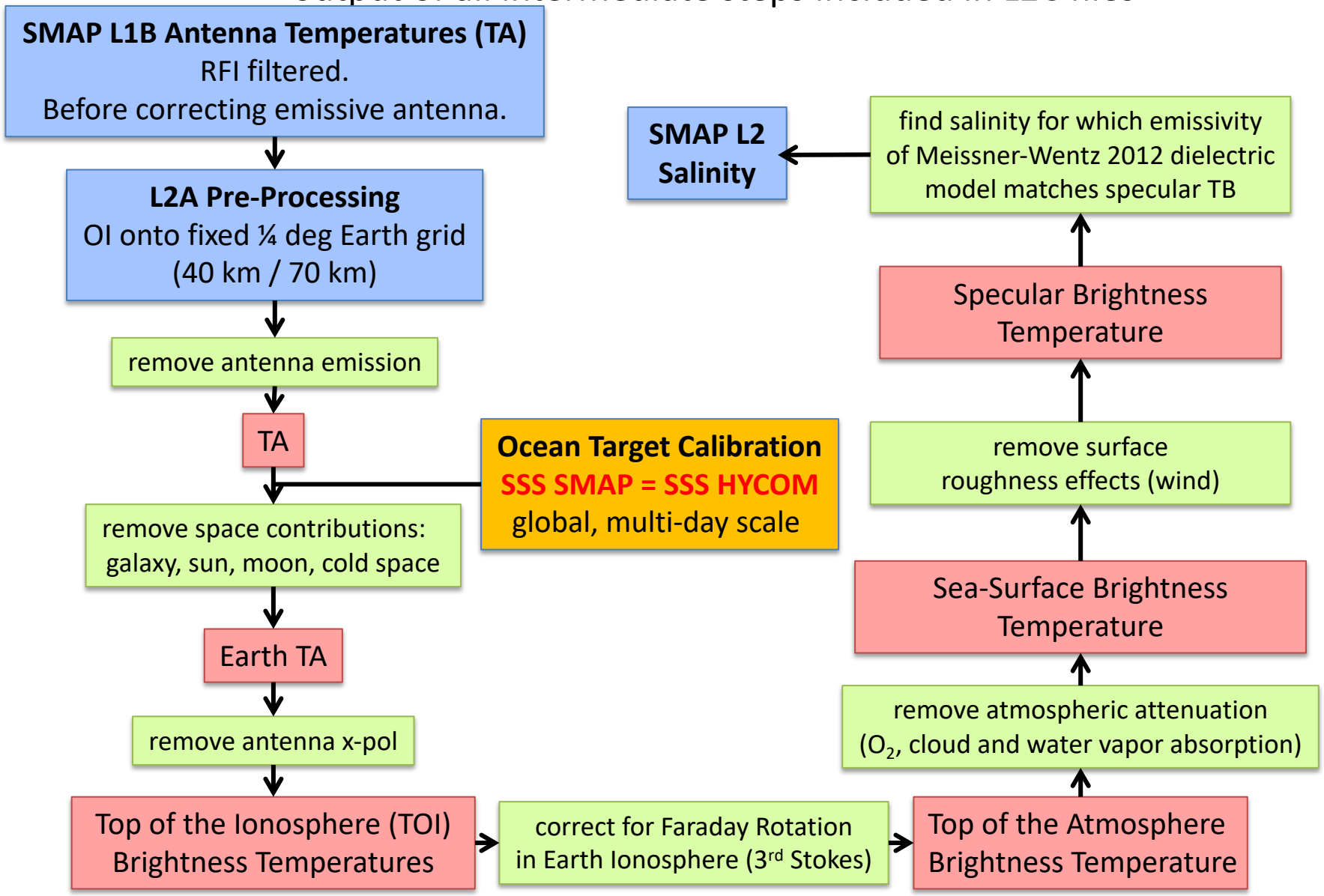
Salinity Retrieval

Geophysical Model (GMF)

- Requires very accurate GMF to remove all these signals
  - 0.2 psu salinity accuracy requires 0.1 Kelvin radiometric accuracy
  - worse in cold water
- We cannot use the Level 1 brightness SMAP temperatures from NSIDC for retrieving salinity
  - Very good RFI filter
  - Recent Version 4 L1B SMAP TB improved from prior versions
  - radiometric accuracy ~ 1 Kelvin
  - Does not fulfill the salinity accuracy requirements: galaxy, atmosphere, emissive antenna, cross-pol, wind roughness
- RSS SMAP ocean products
  - start from TA (antenna temperature) before correcting for emissive antenna
  - L1B TB processing
- We cannot use canned radiative transfer models (community RTM, …) to retrieve salinity
  - TB assimilation

SMAP V3 Salinity Retrieval Algorithm

output of all intermediate steps included in L2C files



SMAP V3 Salinity Retrieval Algorithm

Major Changes from V2 Release

1. **GMF: Consistent with Aquarius V5 release**.
   - i. Meissner Wentz dielectric model.
   - ii. Liebe oxygen absorption (important to mitigate biases in Aquarius V5).
   - iii. Wind emissivity. (Caveat: different ancillary wind speeds).
   - iv. Galaxy (based on SMAP fore – aft, already implemented in V2).
   - **v. Use ARGO as reference SSS to derive GMF. Avoid biases between ARGO/HYCOM.**
2. CCMP ancillary wind speed + direction.
3. Improved land correction.
4. Input SMAP Version 4 L1B TA (latest calibration).
5. Include IMERG rain rate (L2).
   - Resampled to SMAP resolution: 40 km/70 km.
   - Used for rain flagging (comparison with ARGO).
   - Used for atmospheric cloud water correction (instead of NCEP cloud water).

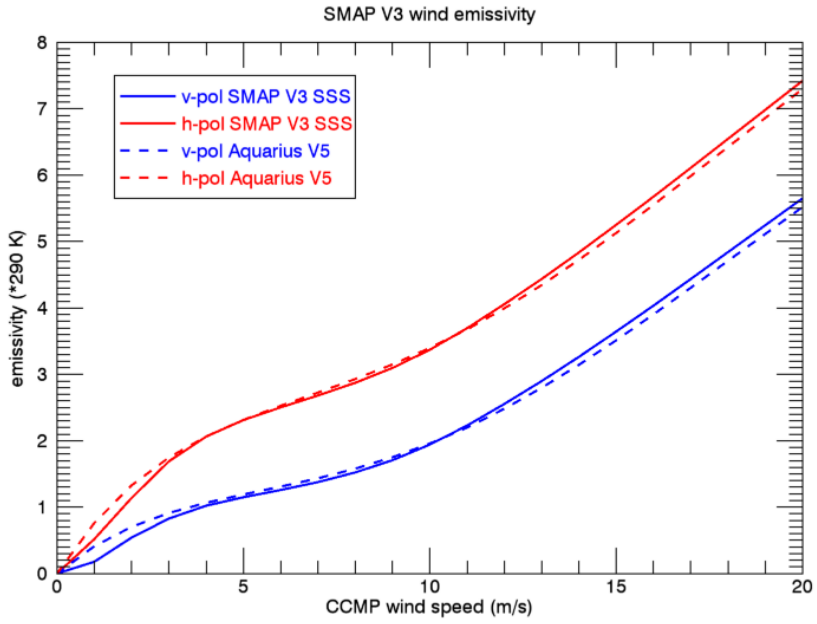
Surface Roughness Correction

CCMP (Cross Calibrated Multi-Platform) Winds

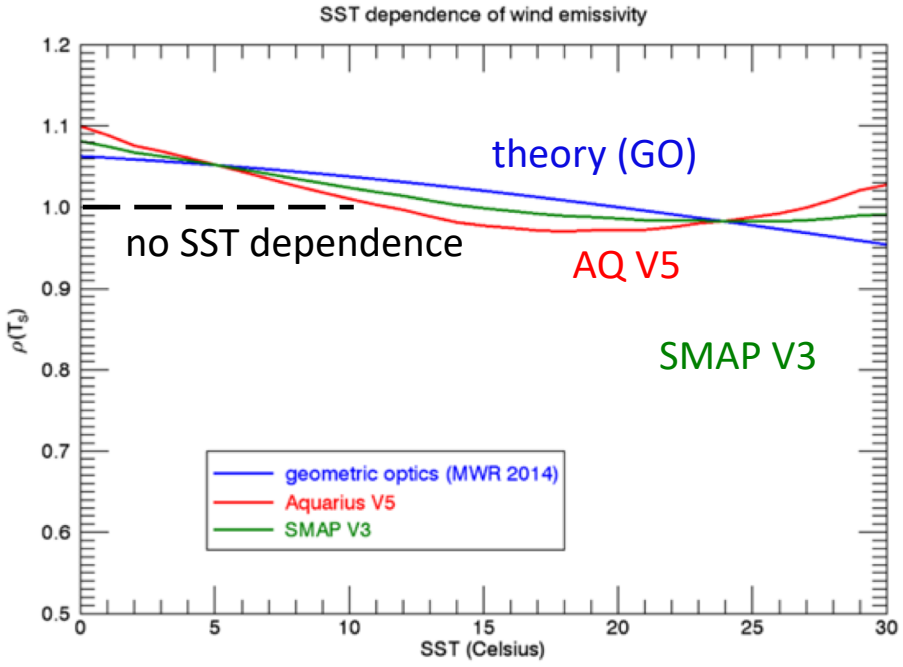
- **Surface roughness is the largest error source**
  - **0.3 m/s error in wind speed makes 0.2 psu error in SSS**
- SMAP lost its scatterometer.
  - Information in radiometer channels is not sufficient to retrieve salinity and wind speed simultaneously.
  - SMAP V/H response to increase in wind is similar to decrease in salinity.
  - **Need external wind speed in surface roughness correction.**
- CCMP for SMAP V3:
  - Blended Level 4 wind vector product.
  - Variational Assimilation Method (VAM): RSS satellite wind fields + NWP background field.
  - V1: R. Atlas et al. 1996 + 2012, BAMS.
  - V2: produced by C. Mears at RSS.
- **SMAP salinity retrievals use near-real time CCMP V2.0**
  - All RSS radiometers (WindSat, AMSR2, SSMIS, GMI).
  - NCEP GDAS as background field. 6 hourly. 0.25°. Space-time interpolated to SMAP.

Wind Emissivity Model

SMAP V3 – Aquarius V5
Code provided with SMAP V3 release



wind speed dependence

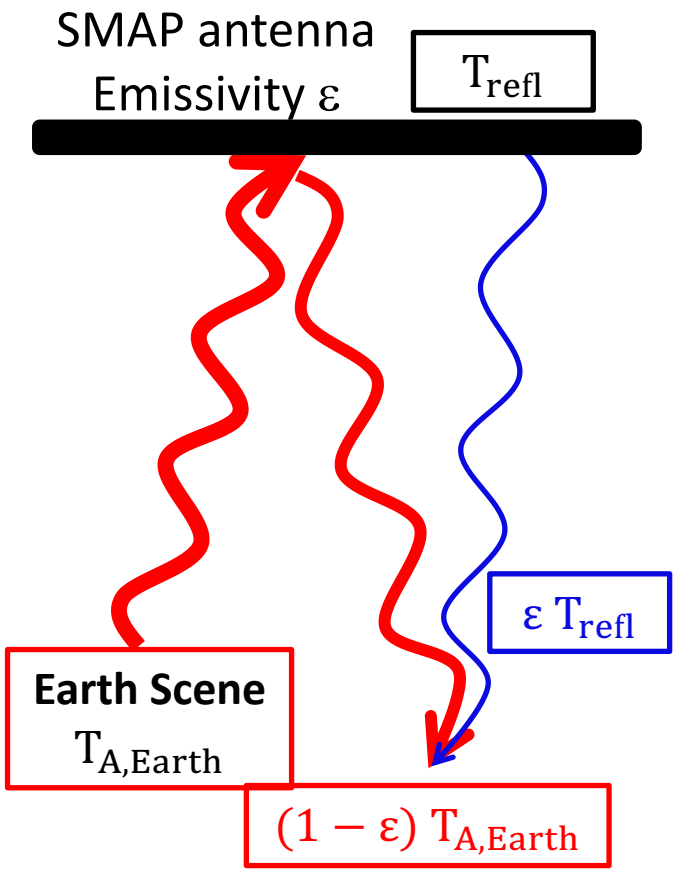


multiply by small SST dependence

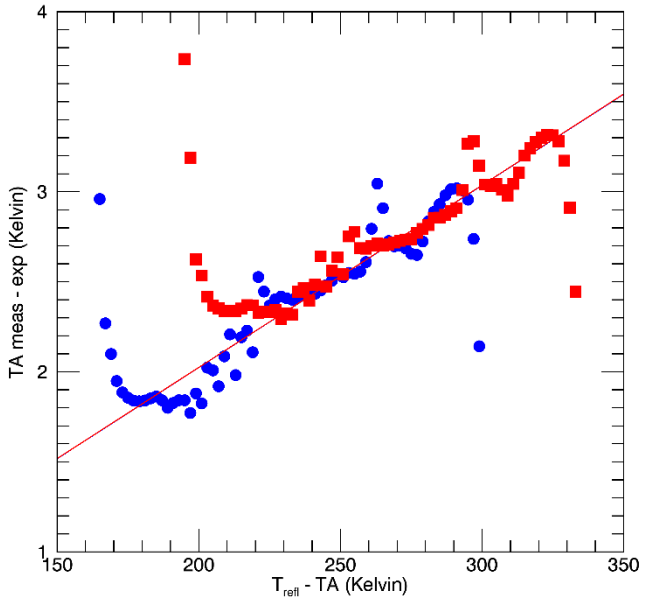
Aquarius V5 uses HHH wind speed (Aquarius scatterometer). SMAP V3 uses CCMP wind speed. There are small systematic differences between these ancillary wind speeds.
Rederiving GMF with different wind speed gives slightly different results.

Emissive Antenna

requires additional calibration effort



- The Aquarius antenna was not emissive.
- The SMAP reflector mesh and component of the feedhorn are **lossy (emissive).**
- $T_A = T_{A,Earth} + \varepsilon\,(T_{refl} - T_{A,Earth})$
- **Emissivity** about 1%. This is **4 times larger than pre-launch value.**



Reflector Temperature

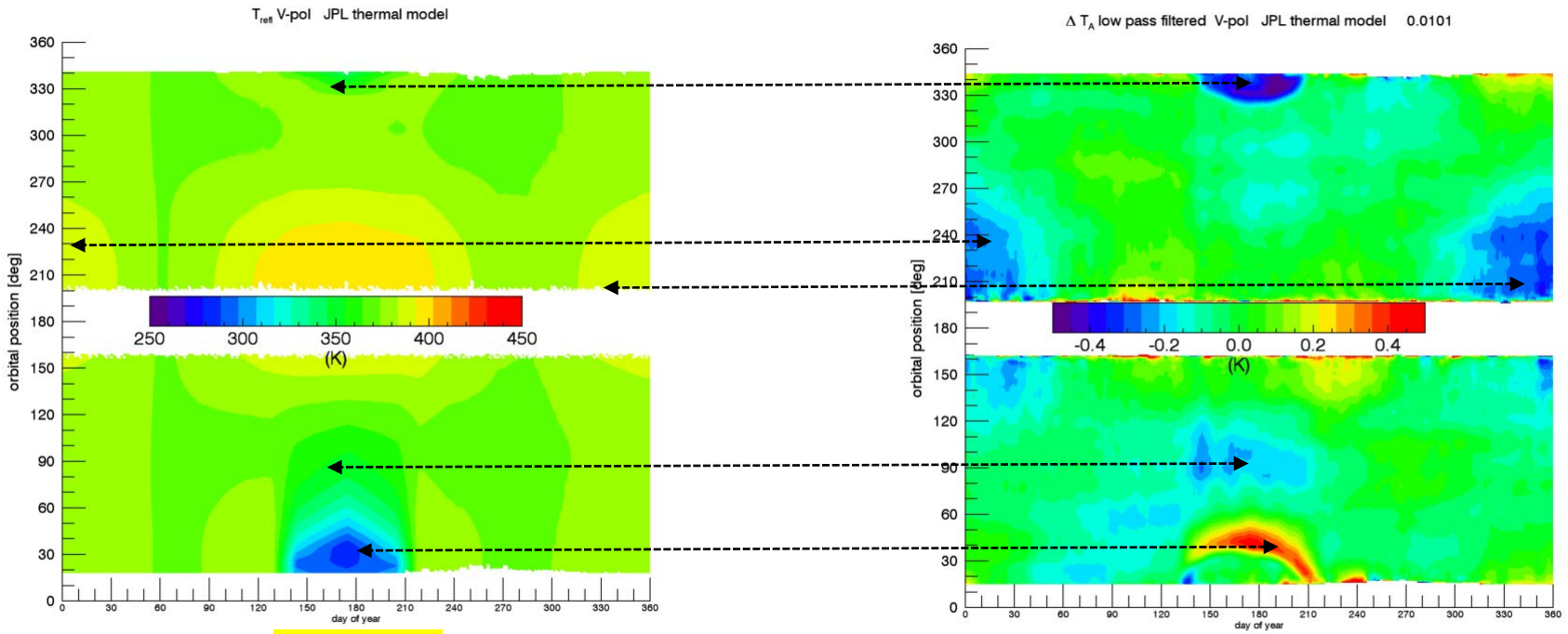
JPL thermal model needs empirical adjustments.

orbit position

DOY

T_{refl}: JPL thermal model

TA Bias



Eclipse Season

Correction for Land Intrusion

Sidelobe Correction based on Orbit Simulator

Desired Quantity
Footprint-Averaged T_B

$$\mathbf{T}_{\mathbf{B},3dB} = \frac{\int_{3dB\ footprt} \mathbf{T}_{\mathbf{BE},toa}\left(\bar{\theta}_i\right) dA}{\int_{3dB\ footprt} dA}$$

Measured Quantity
T_B averaged over 4π steradians

$$\mathbf{T}_A = \frac{1}{4\pi}\int_{4\pi} \mathbf{G}(\mathbf{b})\boldsymbol{\Psi}(\phi)\mathbf{T}_B \frac{\partial\Omega}{\partial A} dA \qquad \mathbf{T}_{\mathbf{B},mea} = \mathbf{A}\cdot\mathbf{T}_A$$

G: Antenna gain **A**: Antenna pattern correction matrix **Ψ**: Faraday Rotation

Sidelobe Correction

$$\Delta\mathbf{T}_B = \mathbf{T}_{\mathbf{B},3dB} - \mathbf{T}_{\mathbf{B},mea}$$

The 3 dB brightness temperature $\mathbf{T_{B,3dB}}$ and the measured brightness temperatures $\mathbf{T_{B,mea}}$ are found using the on-orbit simulator.

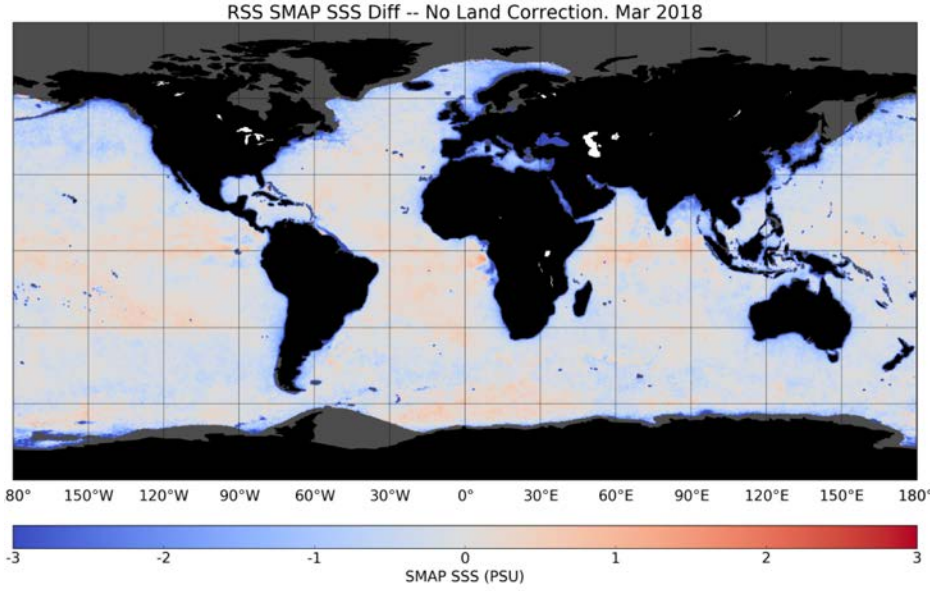
The integration over the Earth's surface is at a spatial resolution of 1 km over the main lobe of the antenna. A coarser resolution is used outside the main lobe.

Forward Model: Land emission RTM using climatology of soil moisture + LST (NCEP).

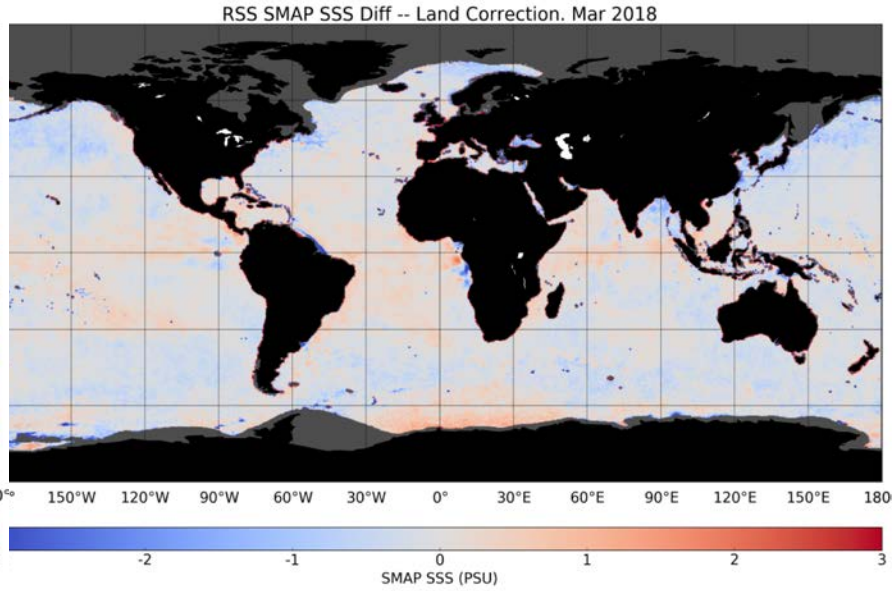
SMAP V3 Sidelobe Correction Table

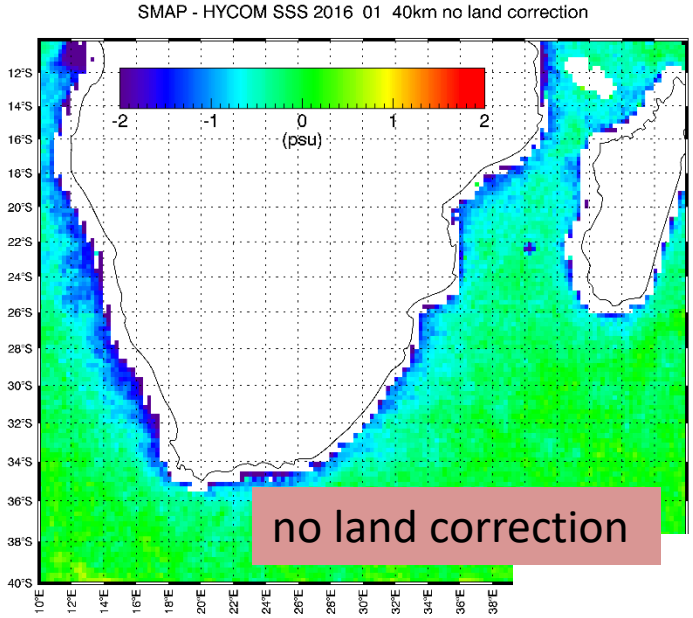
polarization	(2 elements, v-pol, h-pol)
cell longitude	(720 elements in 0.5° increment)
cell latitude	(361 elements in 0.5° increment)
ascending/descending	(2 elements)
scan angle	(30 elements in 12° increments)
month	(12 elements)

No Land Correction

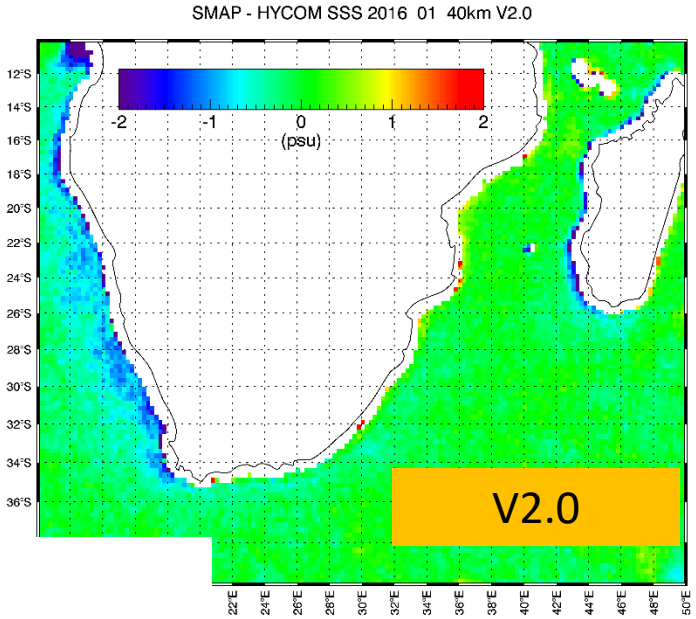


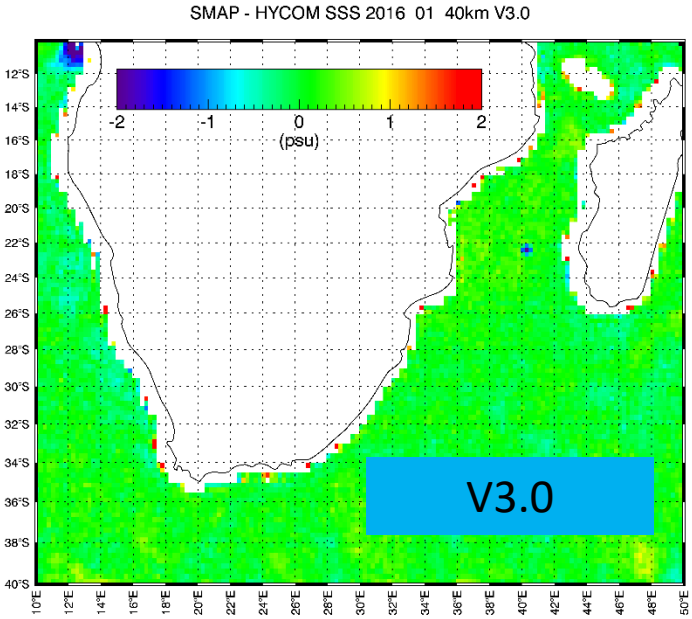
V3.0 Land Correction





SMAP – HYCOM L3 monthly





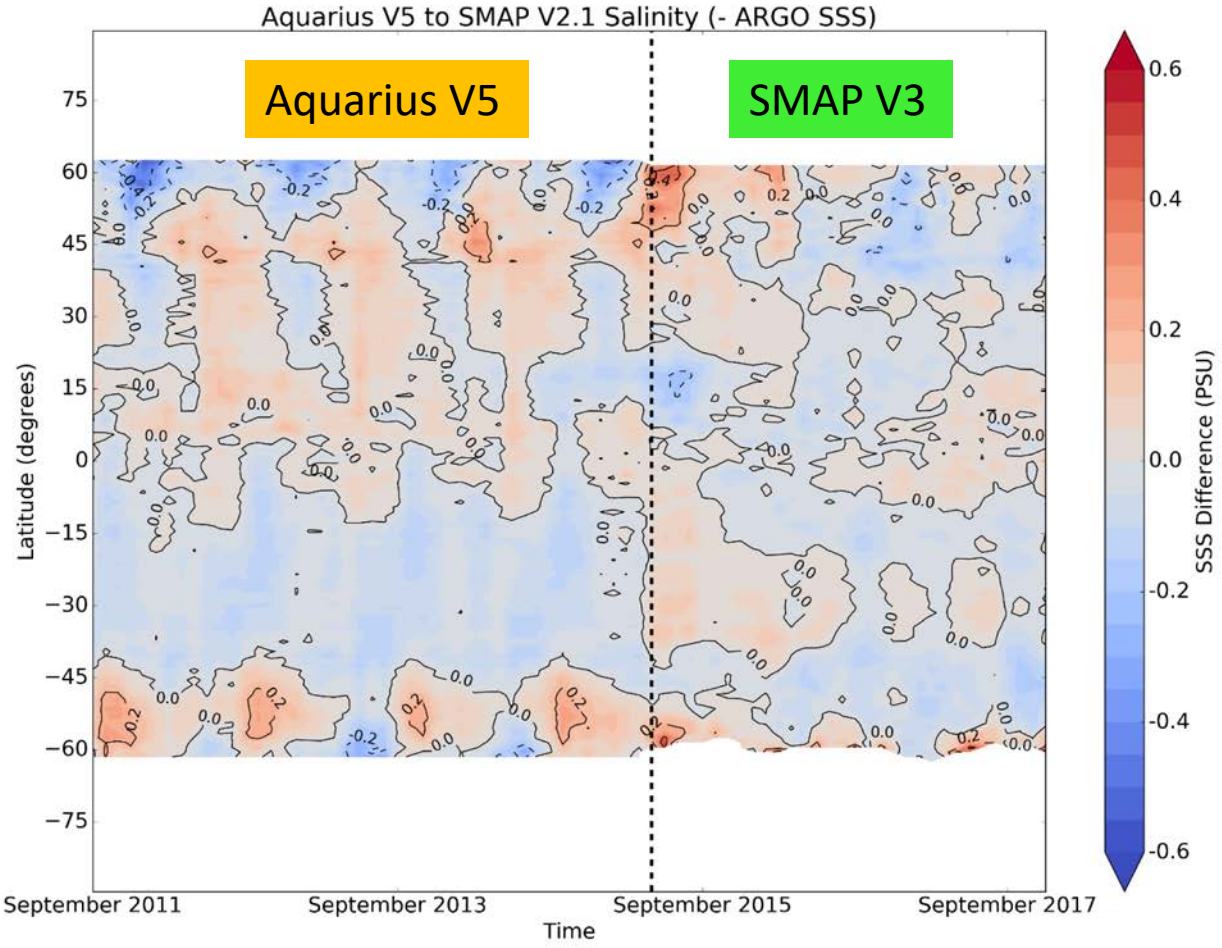
V3.0 land correction performs well up to about 60 km from the coast (1% land contamination).

Degrades closer to coast.

Work in progress to improve.

Aquarius – SMAP Continuity

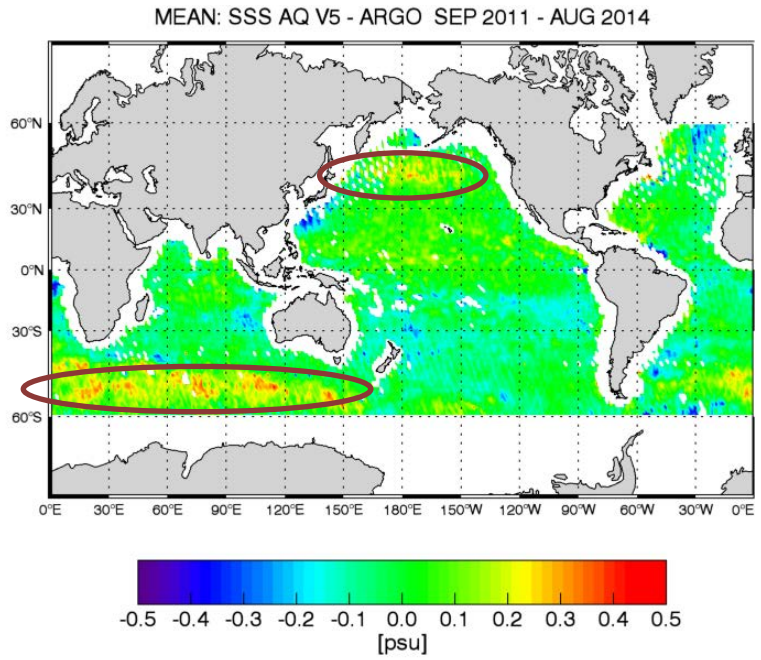
use ARGO as common reference



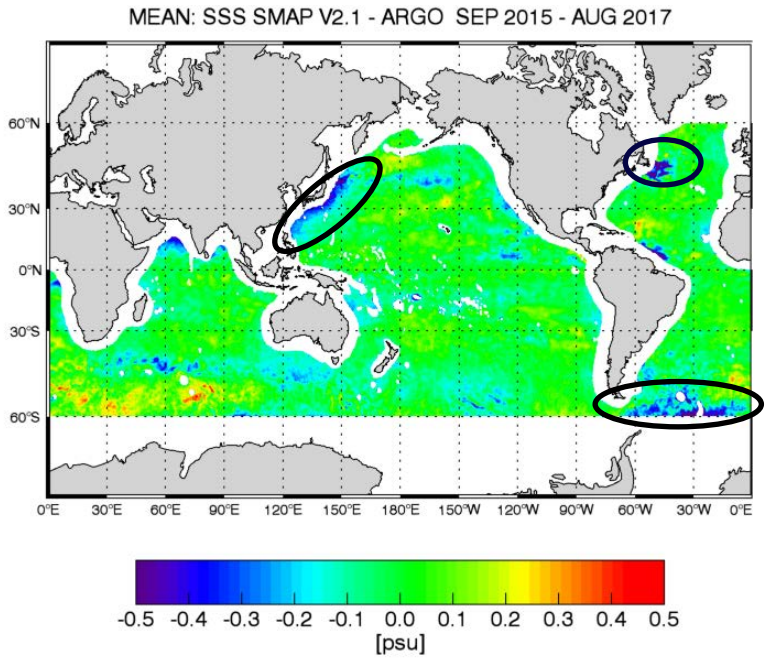
Aquarius – SMAP Continuity

use ARGO as common reference

Aquarius V5 (2012 – 2014) - ARGO



SMAP V3 (2016 – 2017) - ARGO



Aquarius – SMAP Continuity

NASA SCPS

- Residual biases in Aquarius V5 and SMAP V3
- Track down their causes..
  - Wind roughness
  - Galaxy
  - ?
- Differences in sensors and retrieval
  - Ancillary wind speed input
    - Aquarius scatterometer in Aquarius V5 vs CCMP in SMAP V3
  - Different looking geometry
    - Aquarius fixed vs SMAP scanning
    - Directional dependent biases may average out in SMAP.
- Need to keep consistency in GMF for both products

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Article

The Salinity Retrieval Algorithms for the NASA Aquarius Version 5 and SMAP Version 3 Releases

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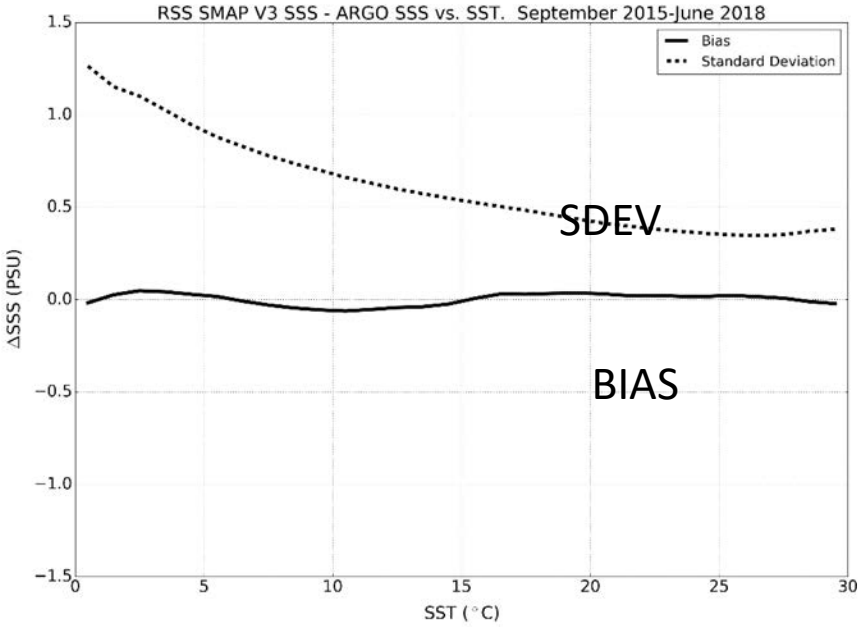
Abstract: The Aquarius end-of-mission (Version 5) salinity data set was released in December 2017. This article gives a comprehensive overview of the main steps of the Level 2 salinity retrieval algorithm. In particular, we will discuss the corrections for wind induced surface roughness, atmospheric oxygen absorption, reflected galactic radiation and side-lobe intrusion from land surfaces. Most of these corrections have undergone major updates from previous versions, which has helped mitigating temporal and zonal biases. Our article also discusses the ocean target calibration for Aquarius Version 5. We show how formal error estimates for the Aquarius retrievals can be obtained by perturbing the input to the algorithm. The performance of the Aquarius Version 5 salinity retrievals is evaluated against salinity measurements from the ARGO network and the HYCOM model. When stratified as function of sea surface temperature or sea surface wind speed, the difference between Aquarius Version 5 and ARGO is within ±0.1 psu. The estimated global RMS uncertainty for monthly 100 km averages is 0.128 psu for the Aquarius Version 5 retrievals. Finally, we show how the Aquarius Version 5 salinity retrieval algorithm is adapted to retrieve salinity from the Soil-Moisture Active Passion (SMAP) mission.

Backup Slides

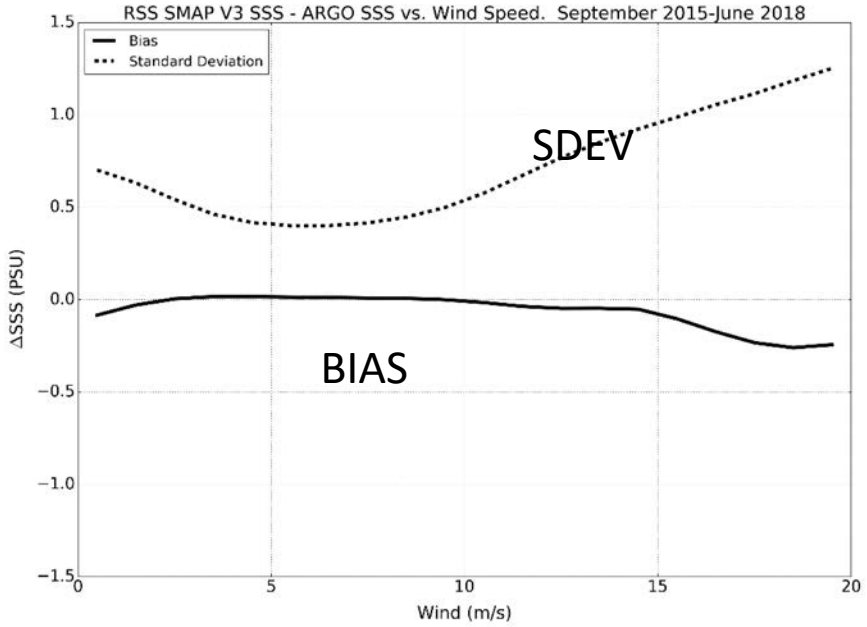
RSS SMAP V3.0 Level 2 – ARGO

Open Ocean. Binned v SST and Wind Speed

VS. SST



VS. WIND SPEED



No biases over whole SST range and wind speed range (< 15 m/s).
Consistency of GMF (dielectric model, wind emissivity model).